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Essential element contents in food groups from the second Brazilian total diet study

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Abstract Total diet study (TDS) has been considered as one of the most appropriate approaches to estimate dietary exposure of essential elements. This paper presents preliminary results of concentrations and average dietary daily intakes of Ca, Co, Cr, Fe, K, Na, Se and Zn from the 2nd Brazilian TDS. Nineteen groups from a Food List which represents the daily intake of the population from the Brazilian southeastern region were analyzed by instrumental neutron activation analysis. The dietary daily intake values for Ca (641 mg), Fe (19.6 mg), K (2738 mg), Na (2466 mg), Se (56.4 μg), and Zn (15.3 mg) were higher than the 1st Brazilian TDS.

Keywords Brazilian total diet · Essential elements · Instrumental neutron activation analysis · Dietary intake

Introduction

Total diet study (TDS) is an approach to estimate the daily dietary intakes of the essential and toxic elements for a large-scale population over a specific period of time. World Health Organization (WHO) incentivates countries to carry out their own TDS.

The TDS is based on the evaluation of food samples representing the nutritional evaluation of the studied population. These samples are presented in a Food List, which lists the types and quantities of the foods consumed by this population. The development of the TDS includes, besides the definition of the Food List, the kitchen preparation of the food samples as ready-to-consume; the analysis in laboratory; and the combination of the data obtained by analysis in laboratory and individual daily consumption data by national surveys. This results in an estimate of the dietary intakes of these elements [1–3].

TDS has been conducted worldwide. Two Brazilian TDS to provide measurements of elements have been developed by the Neutron Activation Laboratory (LAN) at Nuclear Energy Research Institute (IPEN-CNEN/SP). There are no previous experiences in Brazil using the TDS methodology [4, 5].

The food consumption of both TDS was based on the Household Budget Survey (HBS), conducted by the Brazilian Institute of Geography and Statistics (IBGE).

The 1st Brazilian TDS for São Paulo State was performed in 2005–2009. It was based on data from the 2002–2003 HBS [4, 5]. The 2nd Brazilian TDS is being presently developed nowadays, for the southeastern region of Brazil. It is an updated TDS, according to the TDS harmonized methodology, at international level [6]. Data were obtained from the 2008–2009 HBS [7].

While the 1st Brazilian TDS contained only foods consumed in the household, this 2nd TDS includes daily individual foods consumed both inside and outside of the household resulting in a total daily individual consumption of the population. The food group approach was chosen over the individual approach so as to provide a smaller number of food samples to the kitchen preparation and analysis.

The Food List included 82 food items reported consumed foods, according to the survey. Since it is unavailable for individual laboratory analyses, foods with similar nutritional composition are grouped together, resulting in

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19 food groups. The Food List reflects the total weight of the medium daily consumption of the southeastern region population (1617.97 g per capita day^{-1}) [6].

The objective of this paper was to evaluate dietary intakes of Ca, Co, Cr, Fe, K, Na, Se and Zn in the 19 food groups from the Food List of the 2nd Brazilian TDS.

Experimental

Food list

Information about food consumption originated from the 2008–2009 HBS, by the IBGE from May 2008 to May 2009. The 2008–2009 HBS includes, firstly, personal food consumption out of the household, by Analysis of Personal Food Consumption for Brazilian regions. Of the 14,078 households researched, 3064 were randomly selected as the sub-sample for the Analysis of Personal Food Consumption, to obtain data of 7302 inhabitants aged 10 or older, in the urban and rural areas of the region, representing a population of about 80,005,167 inhabitants from the Brazilian southeastern region. This region comprises 4 states. This region was chosen for this study as it includes São Paulo State, which has been previously studied in the 1st Brazilian TDS [4]. Besides, the southeastern region represents 42 % of the Brazilian population [6, 7].

The criteria of selection for the Food List were the daily individual food consumption in and out of the households. The Food List was composed of 82 food items grouped into 19 food groups, referred to as "ready to-consume". Food items were grouped according to the food group classification, which it is based on similar food nutritional composition. The nineteen resulting food groups are as follows: Beans; Beverages; Cakes and biscuits; Cattle meat; Cereals; Dairy products; Eggs; Fish; Flours, pasta and bread; Fruits; Industrialized meat and offal; Nuts and seeds; Oils and fats; Pizza, snacks, sandwiches, soups, sauces, and mixtures; Pork; Poultry; Salt; Sweets; Vegetables. Since the personal food consumption in and out of the households was included, this Food List reflects the totality of the weight of the medium daily consumption of the Brazilian southeastern region population (1617.97 g per capita day^{-1}) [7]. Table 1 shows the food items of each food group and the weight for the 19 food groups analysed in this study.

Table 1 Consumption data of ready-to-consume food groups of the 2nd TDS

Food group	Food items	Total consumption per group (g day^{-1})
Beans	Beans; green beans	223.6
Beverages	Alcoholic beverages; beer; wine; fruit juice; coke soft drink; milk beverages; soy beverages; coffee; tea	563.71
Cakes and biscuits	Cakes; cookie; salted biscuit; stuffed cookies	29.89
Cattle meat	Rump	67.1
Cereals	Polished rice; corn; whole rice	190.9
Dairy products	Pausterized cow whole milk; natural yogurt; white cheese; fruit smoothie; low fat milk	76.0
Eggs	Chicken egg	9.90
Fish	Sardine; coldfish; sardine in oil	14.9
Flours, pasta and bread	French loaf; pasta based mixtures; wheat flour; instantaneous pasta; pasta; stuffing; breakfast cereal; cassava flour; whole wheat bread	108.27
Fruits	Orange; banana; apple; papaya; tangerine; water melon; mango, fruit salad; acai berry, grape; pineapple	81.89
Industrialized meat and offal	Sausage; cooked sausage; mortadella; ham; bovine liver	14.29
Nuts and seeds	Nuts and seeds	0.2
Oils and fats	Soil oil	7.60
Pizza, snacks, sandwiches, soups, sauces, and mixtures	Pizzas; snacks; appetizer; sandwiches; soups; tomato sauce; mixture	80.1
Pork	Slender leg	9.7
Poultry	Chicken	33.0
Salt	Salt	4.6
Sweets	Chocolate; powder chocolate; pudding; crystalized fruit sweet; ice cream	23.8
Vegetables	Potato; cauliflower; tomato; lettuce; cassava; pumpkin; cabbage; carrot; chayote; sweet potato; french fries; cucumber	78.51

Food group preparation for analysis

The food samples were acquired in food stores of São Paulo city, São Paulo State, Brazil. The 500 g criterion per food group was chosen because it was enough for the analyses. The foods were acquired as raw foods. Foods in each food group were prepared separately and mixed in the same proportion of food group in the Food List. The foods were prepared as table-ready; meaning that if necessary the foods were prepared as per the normal preparation habits of the studied population. The preparation included: discarding inedible portions (bones, fruit seeds, etc.); washing and rising with deionized water; chopping; blending; mixing; cooking (if necessary) and homogenizing. During the preparation no salt, seasonings, oils or other condiments were added. All water used in food preparation was deionized water and the utensils were of polyethylene or glass.

After the table-ready preparation the foods of the same food groups were mixed and homogenized to form the groups. The food groups (except cakes and biscuits; oil; salt and sweet groups) were freeze-dried at −51 °C for 15 h in a ModulyD Model freeze-dryer (Thermo Electron Corporation). After the freeze-drying process, the food groups were homogeneized and ground to obtain a fine powder for analysis.

Instrumental neutron activation analysis

Preparation of Ca, Co, Cr, Fe, K, Na, Se and Zn standards

Standards of Ca, Co, Cr, Fe, K, Na, Se and Zn were prepared from appropriate dilutions of their Spex solutions. Aliquots (25–100 μL) taken from such solutions were pipetted onto Whatman 40 filter paper and then dried under an infrared lamp. After drying, filter papers were transferred to clean polyethylene bags. Standards were prepared with the following masses: 992 μg for Ca, 2.48 μg for Co, 2.48 μg for Cr, 495 μg for Fe, 990 μg for K, 12.4 μg for Na, 2.48 μg for Se and 24.6 μg for Zn.

Irradiation

About 150–200 mg of freeze-dried samples and 200 mg of reference materials were weighted in polyethylene bags. Sweets, Oils and fats and Beverages food groups were weighted in polyethylene capsules. For irradiation, the food group samples, reference materials and element standards were simultaneously submitted for 8 h under a thermal neutron flux of 4.5–6.5 $\times$ 10^{12} n cm^{-2} s^{-1} at the nuclear research reactor IEA-R1 of Nuclear and Energy Research Institute (IPEN/CNEN-SP) in São Paulo, Brazil.

Gamma spectrometry

After appropriate decay periods (5 days to determine ^{47}Ca, ^{42}K, ^{24}Na, and 15–20 days for ^{60}Co, ^{51}Cr ^{59}Fe, ^{75}Se and ^{65}Zn), γ-ray spectra of food group samples, reference material and element standards were measured using two counting systems: Model POP-TOP EG&G Ortec and GX 2020 Canberra HPGe detectors. These detectors were coupled to an EG&G Ortec and Canberra card and associated electronics. Spectrum analysis was carried out using VISPECT software, in TURBOBASIC language.

The concentrations of Ca, Na, K, Fe, Zn, Co, Cr and Se in the freeze-dried food groups were determined through the following gamma-ray energies 159 keV for ^{47}Ca, 1368 keV for ^{24}Na; 1525 keV for ^{42}K; 1099 keV for ^{59}Fe, 1115 keV for ^{65}Zn, 1332 keV for ^{60}Co, 320 keV for ^{51}Cr and 264 keV for ^{75}Se.

Table 2 Element concentrations in the reference materials by INAA

Elements	Bovine liver SRM 1577b		Whole egg powder RM 8415		Whole milk powder RM 8435	
	This study mean ± SD[a]	Certified value	This study mean ± SD[a]	Certified value	This study mean ± SD[a]	Certified value
Ca mg kg^{-1}	nd	116 ± 4	2574 ± 339 (4)	2480 ± 190	9480 ± 219 (3)	9220 ± 490
Cr mg kg^{-1}	0.307 ± 0.030 (4)	–	0.374 ± 0.060 (4)	0.38 ± 0.18	nd	(0.5)[b]
Fe mg kg^{-1}	188.2 ± 8.3 (4)	184 ± 15	110.4 ± 8.5 (4)	112 ± 16	2.26 ± 0.33 (3)	1.8 ± 1.1
K %	0.985 ± 0.079 (4)	0.994 ± 0.002	0.284 ± 0.023 (4)	0.319 ± 0.037	1.16 ± 0.13 (3)	1.363 ± 0.047
Na %	0.219 ± 0.010 (4)	0.242 ± 0.006	0.340 ± 0.068 (4)	0.377 ± 0.034	0.307 ± 0.023 (3)	0.356 ± 0.040
Se mg kg^{-1}	0.759 ± 0.080 (4)	0.73 ± 0.06	1.357 ± 0.091 (4)	1.39 ± 0.17	0.135 ± 0.006 (3)	0.131 ± 0.014
Zn mg kg^{-1}	120.0 ± 4.5 (4)	127 ± 16	64.7 ± 0.8 (4)	67.5 ± 7.6	27.5 ± 1.8 (3)	28.0 ± 3.1

nd not determined

[a] Mean and standard deviation of (*n*) individual determinations

[b] Informative value

Table 3 Results of the element concentrations in freeze-dried food groups

Food groups	Mean values and standard deviation (*n*)							
	Ca (mg kg^{-1})	Na (mg kg^{-1})	K (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Co (μg kg^{-1})	Cr (μg kg^{-1})	Se (μg kg^{-1})
Beans	969 ± 89 (3)	7.12 ± 0.67 (3)	7115 ± 458 (3)	67.0 ± 5.4 (3)	19.6 ± 1.3 (3)	86 ± 14 (3)	<50	<60
Beverages	675 ± 20 (2)	807 ± 10(2)	4777 ± 24 (2)	16.5 ± 3.6 (2)	8.10 ± 0.90 (2)	56.1 ± 4.9 (2)	<30	<20
Cakes and biscuits	735 ± 35 (3)	4647 ± 281 (3)	1732 ± 42 (3)	34.3 ± 3.1 (2)	10.60 ± 0.50 (2)	21.0 ± 2.3 (2)	<40	<35
Cattle meat	171 ± 15 (3)	730 ± 34 (3)	5294 ± 488 (3)	56.7 ± 4.7 (3)	110.4 ± 8.6 (3)	26.4 ± 2.8 (3)	<60	460 ± 32 (3)
Cereals	142.5 ± 4.9 (2)	6.97 ± 0.64 (3)	648 ± 38 (3)	4.10 ± 0.50 (3)	17.4 ± 1.4 (3)	78.2 ± 6.5 (3)	33.4 ± 1.2 (3)	38.3 ± 4.0 (3)
Dairy products	10,483 ± 128 (3)	5482 ± 119 (3)	10,199 ± 225 (2)	4.87 ± 0.74 (2)	38.7 ± 2.2 (3)	9.22 ± 0.68 (2)	<68	184 ± 23 (3)
Eggs	2153 ± 131 (3)	4199 ± 164 (3)	4478 ± 139 (2)	74.0 ± 2.5 (3)	53.7 ± 4.1 (3)	3.77 ± 0.81 (3)	<55	635 ± 32 (3)
Fish	5557 ± 167 (3)	2963 ± 116 (3)	3365 ± 53 (2)	33.5 ± 2.4 (3)	32.5 ± 1.0 (3)	15.51 ± 0.78 (3)	<126	762 ± 30 (3)
Flours, pasta and bread	352 ± 15 (2)	5553 ± 127 (3)	1629 ± 43 (3)	63.4 ± 3.6 (3)	12.0 ± 1.1 (3)	9.82 ± 0.57 (3)	66.2 ± 4.0 (2)	109.5 ± 9.5 (3)
Fruits	526 ± 47 (3)	94.3 ± 4.0 (3)	7815 ± 388 (3)	6.76 ± 0.49 (3)	7.40 ± 0.18 (3)	19.4 ± 2.4 (3)	18.8 ± 4.2 (2)	<25
Industrialized meats and offal	834 ± 19 (2)	12,925 ± 1705 (3)	3512 ± 316 (2)	45.3 ± 2.3 (3)	59.7 ± 3.8 (3)	43.7 ± 1.2 (3)	<55	315 ± 14 (2)
Nuts and seeds	1057 ± 101 (3)	658 ± 44 (3)	5301 ± 458 (3)	35.17 ± 0.79 (3)	39.1 ± 1.9 (3)	255 ± 36 (3)	53.4 ± 9.9 (2)	6661 ± 902 (3)
Oils and fats*	<60	0.90 ± 0.40	<5	3.1 ± 0.3	<2	<20	<20	<15
Pizza, snacks, sandwiches, soups, sauces, and mixtures	2530 ± 74 (2)	11,509 ± 979 (3)	4754 ± 239 (3)	34.3 ± 3.6 (3)	27.03 ± 0.87 (3)	39.1 ± 1.0 (3)	<48	<35
Pork	263 ± 37 (3)	1256 ± 60 (3)	5963 ± 92 (3)	25.81 ± 0.36 (3)	87.3 ± 0.7 (3)	8.4 ± 1.0 (2)	62.5 ± 3.5 (2)	343 ± 13 (3)
Poultry	395 ± 27 (3)	1997 ± 20 (3)	9966 ± 512 (3)	21.13 ± 0.40 (3)	40.6 ± 1.5 (3)	6.5 ± 1.4 (3)	<55	351 ± 45 (3)
Salt*	<820	256,160 ± 6846	<2000	6.0 ± 2.0	<2	<20	<20	<15
Sweets	730 ± 20 (2)	335 ± 33 (2)	2660 ± 332 (2)	37.9 ± 2.0 (2)	13.60 ± 0.80 (2)	141 ± 30	<50	<20
Vegetables	3653 ± 362 (3)	307 ± 28 (3)	18,141 ± 2293 (3)	33.2 ± 5.6 (3)	21.0 ± 1.8 (3)	32.75 ± 0.10 (2)	<60	<20

n number of determinations, <*LD* detection limit

* Values from Avegliano et al. [4]

Table 4 Element concentrations in table-ready food groups

Food Groups	Concentrations in mg kg^{-1}					Concentrations in μg kg^{-1}		
	Ca	Na	K	Fe	Zn	Co	Cr	Se
Beans	318 ± 29	2.34 ± 0.22	2334 ± 150	22.0 ± 1.8	6.4 ± 0.4	28.3 ± 4.8	–	–
Beverages	159.3 ± 1.0	190.5 ± 2.4	1126.9 ± 5.7	3.90 ± 0.85	1.91 ± 0.21	13.2 ± 1.2	–	–
Cakes and biscuits	753 ± 35	4647 ± 281	1732 ± 42	34.3 ± 3.1	10.57 ± 0.49	21.0 ± 2.3	–	–
Cattle meat	125 ± 11	532 ± 25	3859 ± 356	41.4 ± 3.5	80.5 ± 6.3	19.2 ± 2.0	–	335 ± 23
Cereals	76.2 ± 2.6	3.73 ± 0.34	347 ± 21	2.32 ± 0.35	9.3 ± 0.7	41.8 ± 3.5	17.85 ± 0.64	20.5 ± 2.1
Dairy products	2872 ± 35	1502 ± 33	2795 ± 62	1.33 ± 0.20	10.60 ± 0.60	2.52 ± 0.19	–	50.5 ± 6.3
Eggs	510 ± 31	995 ± 39	1061 ± 33	17.55 ± 0.59	12.73 ± 0.97	0.89 ± 0.19	–	150.4 ± 7.6
Fish	2198 ± 66	1172 ± 46	1331 ± 21	13.3 ± 1.0	12.86 ± 0.40	6.13 ± 0.32	–	301 ± 12
Flours, pasta and bread	225 ± 10	3555 ± 81	1043 ± 28	40.6 ± 2.3	7.71 ± 0.69	6.29 ± 0.37	39.8 ± 2.6	70.1 ± 5.7
Fruits	188 ± 17	33.8 ± 1.4	2798 ± 139	2.4 ± 0.2	2.6 ± 0.1	6.9 ± 0.9	7.7 ± 2.9	–
Industrialized meats and offal	658 ± 15	10,191 ± 1344	2295 ± 822	25.7 ± 1.8	47.0 ± 3.0	34.5 ± 0.66	–	248 ± 11
Nuts and seeds	1057 ± 101	658 ± 44	5301 ± 458	35.2 ± 0.8	39.1 ± 1.9	255 ± 36	53 ± 11	6661 ± 902
Oils and fats*	–	0.90 ± 0.40	–	3.1 ± 0.30	–	–	–	–
Pizza, snacks, sandwiches, soups,sauces, and mixtures	765 ± 22	3481 ± 296	1438 ± 72	10.4 ± 1.1	8.18 ± 0.26	11.8 ± 0.15	–	–
Pork	178 ± 25	848 ± 41	4025 ± 62	17.42 ± 0.24	58.93 ± 0.47	5.66 ± 0.65	42.2 ± 2.4	231.8 ± 8.8
Poultry	185 ± 13	934 ± 10	4664 ± 240	9.89 ± 0.19	19.02 ± 0.70	3.04 ± 0.63	–	164 ± 21
Salt*	–	256,160 ± 6846	–	6.0 ± 2.0	–	–	–	–
Sweets	730 ± 20	335 ± 33	2660 ± 332	37.9 ± 2.0	13.60 ± 0.80	141 ± 30	–	–
Vegetables	548 ± 54	46.1 ± 4.2	2721 ± 344	4.98 ± 0.84	3.15 ± 0.27	4.92 ± 0.02	–	–

* Values from Avegliano et al. [4]

Results and discussion

The validation of the analytical method applied was performed by analysis of biological reference materials Bovine Liver SRM 1577b, Whole Egg Powder RM 8415 and Whole Milk Powder RM 8435 from the National Institute of Standards and Technology. The results showed good agreement with the certified values, as can be verified in Table 2.

Table 3 presents the concentrations of the elements in the 19 food groups determined by INAA. Table 4 shows the concentration of the elements in table-ready food groups which took into consideration the water loss during the freeze-drying process when needed.

Average daily element intake was calculated by multiplying the individual element concentration in the food groups (Table 4) by the corresponding weight of the ready-to-consume food groups (Table 1). Table 5 shows the mean daily element intakes in each food group as well as the total dietary element intake.

Calcium concentrations in the table-ready food groups ranged from 76.5 mg kg^{-1} (cereals) to 2872 mg kg^{-1} (dairy products). Calcium dietary intakes varied from 0.21 mg day^{-1} (nuts and seeds) to 218.3 mg day^{-1} (dairy products.). Dairy products represent the biggest concentration of Ca and 34 % of the Ca daily intake.

Cobalt concentrations in the table-ready food groups ranged from 0.89 μg kg^{-1} (eggs) to 255 μg kg^{-1} (nuts and seeds). Co intakes varied from 0.0090 μg day^{-1} (eggs) to 7.98 μg day^{-1} (cereals). Cereals represent 26 % of the Co intake of the 2nd TDS.

Chromium concentrations in the table-ready food groups ranged from 7.7 μg kg^{-1} (fruits) to 53 μg kg^{-1} (nuts and seeds). Chromium was detected in only 5 food groups. The daily intake was 8.69 μg day^{-1}. Even though nuts and seeds presented the highest concentration of Cr, they represented the lowest intake of Cr, since this food group is consumed in very small amounts, 0.2 g day^{-1} (Table 1). The Cr content can vary due to the industrialization process of food and during kitchen preparation [8]. Flours, pasta

Table 5 Mean dietary daily intakes of essential elements in the table-ready food groups

Food groups	Dietary daily intake							
	Ca (mg)	Na (mg)	K (mg)	Fe (mg)	Zn (mg)	Co (μg)	Cr (μg)	Se (μg)
Beans	71.1 ± 6.5	0.52 ± 0.05	522 ± 34	4.92 ± 0.4	1.431 ± 0.089	6.3 ± 1.0	–	–
Beverages	89.84 ± 0.10	190.5±	635.3 ± 3.2	0.20 ± 0.48	1.91 ± 0.21	7.97 ± 0.65	–	–
Cakes and biscuits	22.5 ± 1.0	138.9 ± 8.4	51.8 ± 3.3	1.025 ± 0.093	0.316 ± 0.015	0.629 ± 0.069	–	–
Cattle meat	8.37 ± 0.05	35.7 ± 1.7	259 ± 24	2.77 ± 0.23	5.43 ± 0.44	1.29 ± 0.13	–	22.5 ± 1.9
Cereals	14.55 ± 0.52	0.71 ± 0.06	66.2 ± 3.9	0.419 ± 0.051	1.78 ± 0.14	7.98 ± 0.67	3.42 ± 0.12	3.55 ± 0.16
Dairy products	218.3 ± 2.7	114.2 ± 2.5	212 ± 5	0.10 ± 0.02	0.81 ± 0.05	0.19 ± 0.01	–	3.84 ± 0.48
Eggs	5.05 ± 0.31	9.85 ± 0.39	10.5 ± 0.3	0.17 ± 0.01	0.126 ± 0.01	0.009 ± 0.002	–	1.49 ± 0.08
Fish	32.8 ± 1.0	17.46 ± 0.69	19.83 ± 0.31 (1.0)	0.198 ± 0.015	0.192 ± 0.006	0.091 ± 0.005	–	4.48 ± 0.18
Flours, pasta and bread	38.1 ± 1.6	601 ± 14	176.4 ± 4.7	6.9 ± 0.4	1.3 ± 0.12	1.06 ± 0.06	7.17 ± 0.84	11.91 ± 0.97
Fruits	15.4 ± 1.4	2.77 ± 0.11	229 ± 11	0.2 ± 0.02	0.21 ± 0.01	0.57 ± 0.07	0.63 ± 0.24	–
Industrialized meats and offal	9.40 ± 0.22	146 ± 19	33 ± 12	0.510 ± 0.025	0.672 ± 0.043	0.493 ± 0.009		3.55 ± 0.16
Nuts and seeds	0.21 ± 0.02 (0.05)	0.13 ± 0.01 (0.02)	1.06 ± 0.09 (0.06)	0.0070 ± 0.0002 (0.04)	0.0078 ± 0.0004 (0.06)	0.05 ± 0.01 (0.3)	0.011 ± 0.002 (0.09)	1.33 ± 0.18 (2.3)
Oils	–	0.007 ± 0.003	–	0.0236 ± 0.0023	–	–	–	–
Pizza, snacks, etc.	61.3 ± 1.8	279 ± 24	115.2 ± 5.8	0.830 ± 0.087	6.65 ± 0.02	0.950 ± 0.010	–	–
Pork	1.73 ± 0.24 (0.38)	8.23 ± 0.40 (1.0)	39.04 ± 0.6 (2.1)	0.169 ± 0.003 (1.0)	0.571 ± 0.005 (4.5)	0.055 ± 0.007 (0.3)	–	2.25 ± 0.09 (3.9)
Poultry	6.11 ± 0.43 (1.3)	30.7 ± 2.2 (3.7)	154 ± 8 (8.1)	0.33 ± 0.01 (2.0)	0.63 ± 0.02 (4.9)	0.10 ± 0.02 (0.6)	–	5.41 ± 0.69 (9.5)
Salt	–	1178 ± 32	–	0.0276 ± 0.0092	–	–	–	–
Sweets	17.37 ± 0.48	7.97 ± 0.79	63.3 ± 7.9	0.902 ± 0.048	0.324 ± 0.019	3.36 ± 0.71	–	–
Vegetables	43.0 ± 4.2 (9.5)	3.62 ± 0.33 (0.4)	214 ± 27 (11)	0.39 ± 0.07 (2.4)	0.247 ± 0.021 (1.9)	0.386 ± 0.002 (2.1)	—	–
Total ingestion	641 mg day^{-1}	2466 mg day^{-1}	2738 mg day^{-1}	19.6 mg day^{-1}	15.3 mg day^{-1}	30.6 μg day^{-1}	8.69 μg day^{-1}	56.4 μg day^{-1}

Table 6 Mean daily intakes of essential elements for adults from this study comparing to 1st Brazilian TDS and others countries TDS

TDS studies/coutry	Dietary daily intake							
	Ca (mg)	Na (mg)	K (mg)	Fe (mg)	Zn (mg)	Co (μg)	Cr (μg)	Se (μg)
This study/Brazil	641	2466	2738	19.6	15.6	27.3	8.69	56.4
1st TDS/Brazil [4]	275	1928	861	5.7	4.25	–	20.7	9.44
1st HKTDS/Hong Kong [9]	430	2600	1900	8	9.2	9.4	–	140
China-Shenzhen [10]	391	2840	2110	7.28	7.47	–	–	–
2nd TDS/France [11]	786	2653	2854	7.715	7.935			64.4
TDS/Spain [12]	–	–	–	–	19.9–23.8	–	10.8–11.2	125–130
Market basket diets/Swedish [13]	1110	2580	3320	9.2	11.3	–	25	56
TDS/Italy [14]	–	–	–	11	12	29	–	–
The 23rd TDS/Australian [15]	785–1000		3330–4340	9.3–13.4	8.7–13.2	26–33	97–135	106–155
TDS/Lebanon [16]				13	10.97	11.4		

and bread presented 82 % of the Cr daily intake of the 19 food groups, probably due to the addition of Cr during the industrialization process.

Iron concentrations in the table-ready food groups ranged from 1.33 mg kg^{-1} (dairy products) to 40.6 mg kg^{-1} (flours, pasta and bread). The highest Fe concentration is probably occurred due to the fact that in Brazil iron-fortified wheat flour has been used since 2002. Iron intakes varied from 0.0070 mg day^{-1} (nuts and seeds) to 4.92 mg day^{-1} (beans). Beans are the most consumed food group as showed in Table 1, even though it is not the highest concentration in Fe.

The food groups composed of fortified Fe wheat flour products (flours, pasta and bread) and beans were the major contributors to the total Fe intake. It is probably due to low consumption of meats (cattle meat, pork, poultry and fish).

Potassium concentrations in the table-ready food groups ranged from 1043 mg kg^{-1} (flours, pasta and bread) to 5301 mg kg^{-1} (nuts and seeds) and the K dietary intakes varied from 1.06 mg day^{-1} (nuts and seeds) to 635 mg day^{-1} (beverages). The significant dietary sources of potassium, nuts and seeds are diluted by their small amount in the Food List (0.2 g day^{-1}).

In this current study sodium concentrations ranged from 0.90 mg kg^{-1} (oils and fats) to 256,160 mg kg^{-1} (salt).

Selenium was determined in 10 of the 19 analyzed food groups. Selenium concentrations in the table-ready food groups ranged from 20.5 μg kg^{-1} (cereals) to 6661 μg kg^{-1} (nuts and seeds). Food groups based on animal sources had the highest concentrations of Se albeit lower than nuts and seeds. Selenium intakes varied from 1.33 μg day^{-1} (nuts and seeds) to 22.5 μg day^{-1} (cattle meat). Although nuts and seeds are the highest sources of Se, due the small amount consumed they are not important as selenium sources (2.3 % of the Se daily intake). Cattle meat has the most important participation in the daily intake, around 40 % among the 19 food groups.

For Zinc the concentration values in the table-ready food groups ranged from 1.91 mg kg^{-1} (beverages) to 80.5 mg kg^{-1} (cattle meat).

The results of the daily intakes of the essential elements in this study were compared to the 1st Brazilian TDS and with studies from other countries (Table 6).

The results obtained in this study were higher than the 1st Brazilian TDS [4], except for Cr. The intakes of Ca in this Brazilian TDS were lower than most other countries, except for China and Hong Kong. The intakes of Na were quite similar in all the other TDS. Potassium intakes were similar to France TDS and lower than Swedish and Australian TDS. The Fe dietary daily intakes were higher than all other TDS. Zn intakes were higher than most of studies, except for Spain. Cobalt intakes were similar to Italian and Australian TDS and higher than the other studies. Cr and Se intakes were lower than the other studies.

Conclusions

In this study, INAA showed to be a useful and reliable method for the analysis of important essential elements in foodstuffs and providing good precision and accuracy of the results.

Concentrations and dietary daily intake values of eight essential elements were obtained in food groups of the 2nd Brazilian Total Diet Study. Ca, Na, K, Fe, Zn and Se dietary daily intakes were higher than those observed in the 1st Brazilian TDS for the 19 analyzed food groups. The 2nd TDS included foods consumed in and out of the households and consequently a larger variety of food was analyzed in comparison to the 1st TDS which included

only foods consumed in the household. This difference may explain the higher intake values observed in this study.

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References

1. EFSA, FAO and WHO-European Food Safety Authority, Food and Agriculture Organization of the United Nations & World Health Organization (2011a) Towards a harmonized total diet study approach: a guidance document. EFSA J. 9(11): 1–66. http://www.efsa.europa.eu/en/efsajournal/doc/2450.pdf. Accessed 25 Mar 2015
2. EFSA, FAO and WHO-European Food Safety Authority, Food and Agriculture Organization of the United Nations &World Health Organization (2011b) State of the art on total diet studies based on the replies to the EFSA/FAO/WHO questionnaire on national total diet study approaches. Support Publ, 206:1–38. http://www.efsa.europa.eu/en/supporting/doc/206e.pdf. Accessed 25 Mar 2015
3. WHO-World Health Organization (1985) Global environmental monitoring system. Guidelines for the study of dietary intakes of chemical contaminants. WHO Offset Publication 87. http://www.who.int/foodsafety/publications/chem/Guidelines_chem_contam.pdf. Accessed 25 Mar 2015
4. Avegliano RP, Maihara VA, da Silva FF (2011) A Brazilian total diet study: evaluation of essential elements. J Food Comp Anal 24:1009–1016
5. Avegliano RP, Maihara VA (2014) Total diet study: Mg and Mn content estimation of a Market Basket of São Paulo state (Brazil) by Instrumental Neutron Activation. J Radioanal Nucl Chem 299:781–785
6. Avegliano RP, Maihara VA, da Silva FF (2015) Development of the food list for a Brazilian total diet study. Food Sci Technol Camp 35(1):207–212. doi:10.1590/1678-457X.6279
7. IBGE-Brazilian Institute of Geography and Statistics (2011) Consumer expenditure survey 2008–2009: analysis of personal food consumption in Brazil. http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/pof/2008_2009_analise_consumo/pofanalise_2008_2009.pdf. Accessed 25 Mar 2015
8. IOM-Institute of Medicine (2006) Dietary reference intakes: the essential guide to nutrient requirements. The National Academies Press, Washington
9. Centre for Food Safety (2014) Food and Environmental Hygiene Department. The Government of the Hong Kong special administrative region
10. Jiang J, Lu S, Zhang H, Liu G, Lin K, Huang W, Luo R, Zhang X, Tang C, Yingxin Yu (2015) Dietary intake of human essential elements from a total diet study in Shenzhen, Guangdong Province, China. J Food Comp Anal 39:1–7
11. Kalonji E, Sirot V, Noel L, Guerin T, Margaritis I, Leblanc J-C (2015) Nutritional risk assessment of eleven minerals and trace elements: prevalence of inadequate and excessive intakes from the second french total diet study. Eur J Nutr 5:281–296
12. Perelló G, Vicente E, Castell V, Llobet JM, Nadal M, Domingo JL (2015) Dietary intake of trace elements by the population of Catalonia (Spain): results from a total diet study. Food Addit Contam. doi:10.80/19440049.2015.1018844
13. Becker W, Jorhem L, Sundström B, Grawé P (2011) Contents of mineral elements in Swedish market basket diets. J Food Compos Anal 24:279–287
14. Turconi G, Minoia C, Ronchi A, Roggi C (2009) Dietary exposure estimates of twenty-one trace elements from a total diet study carried out in Pavia, Northern Italy. Br J Nutr 101:1200–1208
15. The 23rd Australian Total Diet Study, Food Standards Australia New Zealand (2011). https://www.foodstandards.gov.au/publications/documents/FSANZ%2023rd%20ATDS_v8_.pdf. Accessed 26 Oct 2015
16. Nasreddine L, Nashalian O, Naja F, Itani L, Parent-Massin D, Nabhani-Zeidan M (2010) Dietary exposure to essential and toxic trace elements from a total diet study in an adult Lebanese urban population. Food Chem Toxicol 48:1262–1269